



Selected KSC Applied Physics Lab Responses to Shuttle Processing Measurement Requests

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The KSC Applied Physics Lab has been supporting Shuttle Ground Processing for over 20 years by solving problems brought to us by Shuttle personnel.

Roughly half of the requests to our lab have been to find ways to make measurements, or to improve on an existing measurement process.

This talk will briefly cover five interesting examples.





Number 1: Centering the aft end of the External Tank between the Solid Rocket Boosters



The aft end of the External Tank needs to be centered between the SRBs before being locked down.

Before 1990 this was accomplished by swinging people in harnesses into the gap with large calipers and having them take measurements indicating the adjustment needed.

This was inaccurate, dangerous, and potentially damaging to the tank and boosters.



Number 1: Centering the aft end of the External Tank between the Solid Rocket Boosters



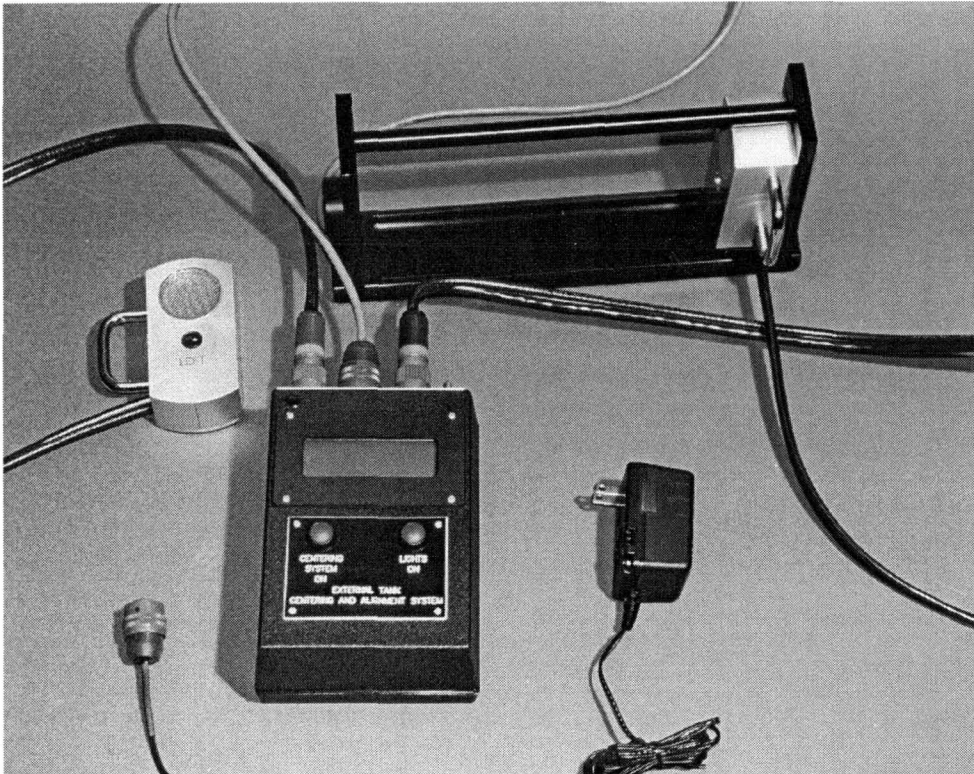
We were asked to construct equipment that could provide these measurements (one for each side) to the move conductor.

The gap is relatively small 10-12 inches and we were asked to provide $1/8^{\text{th}}$ inch accuracy, $1/6^{\text{th}}$ if possible.





Number 1: Centering the aft end of the External Tank between the Solid Rocket Boosters

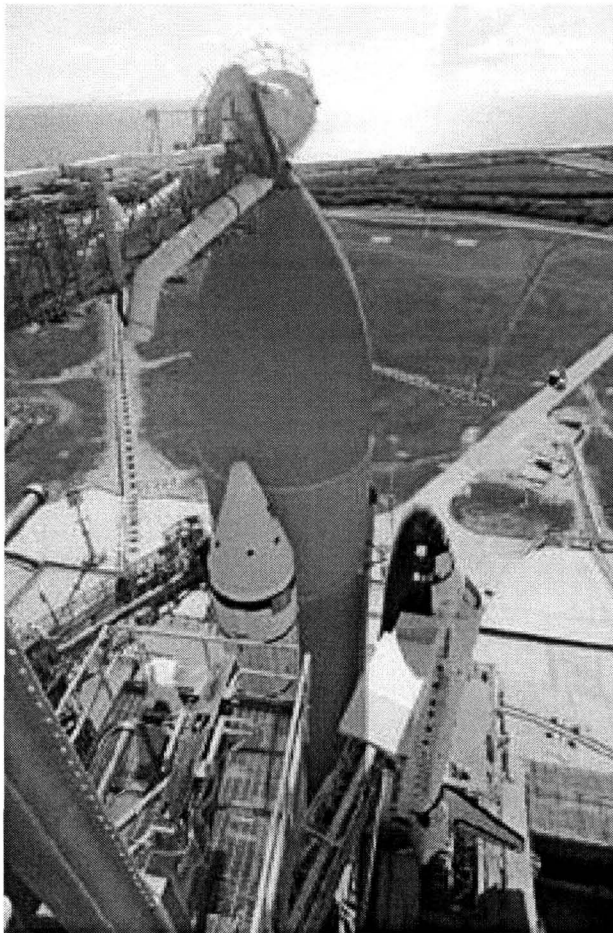


We developed magnetically attached ultrasonic sensor heads that attach to the SRBs and provide measurements to 0.01 inch resolution, about 0.02 inch accuracy, to the move conductor. The hardware was well received and is still in use.

Note: by providing a readout to 0.01 inches we inadvertently changed the measurement requirement. The technicians told us that their management would not allow the use of other technology that was within the original specification, but less than what our unit displayed.



Number 2: Positioning the GOX Vent Hood over the External Tank

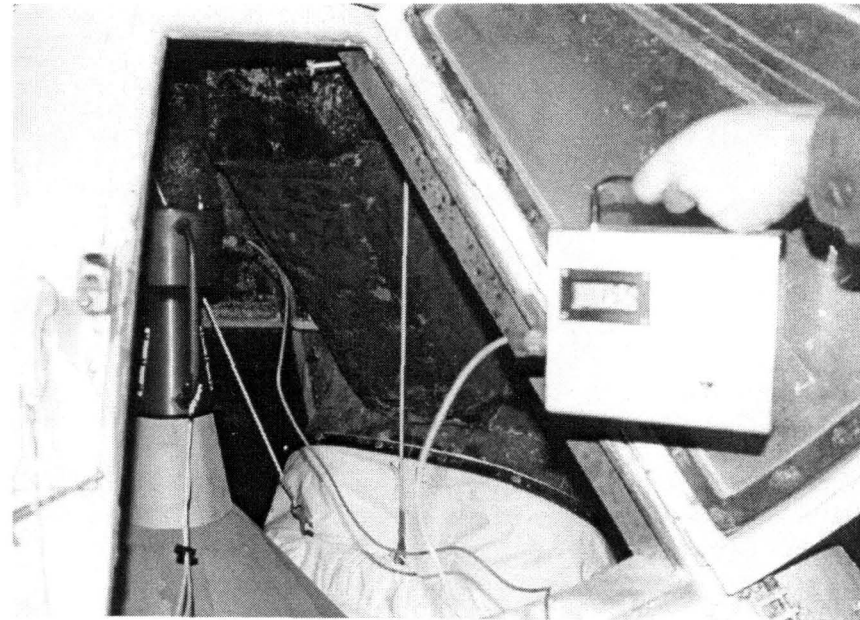
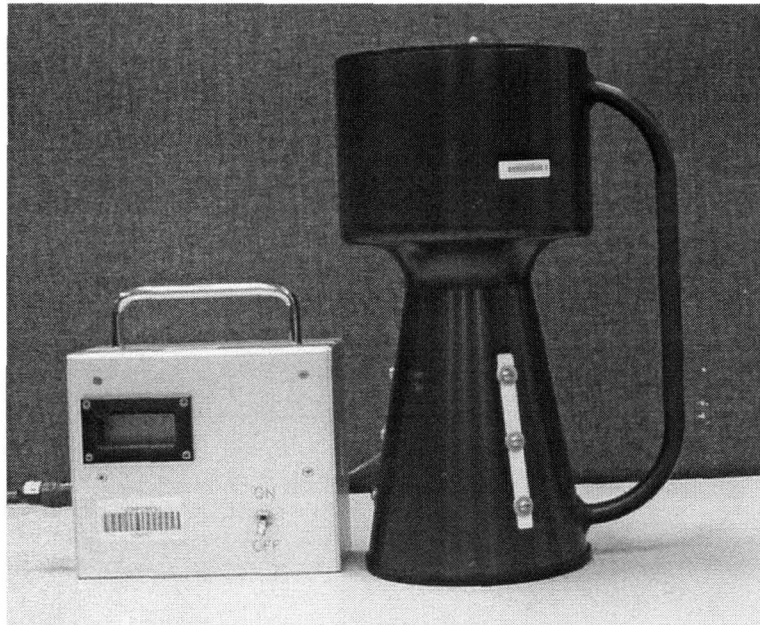


The GOX vent hood, shown lifted over the ET in the figure, must be accurately located to capture oxygen boil-off.

The previous approach used a surveyed grid on the ET and a light beam on hood, but the grid washes off during fueling and took about 24 hours to survey and reapply. This was a potential turnaround time limitation.



Number 2: Positioning the GOX Vent Hood over the External Tank



An ultrasonic rangefinder and laser were built into a fixture that could be located on the ET spike, providing the distance and location measurement.

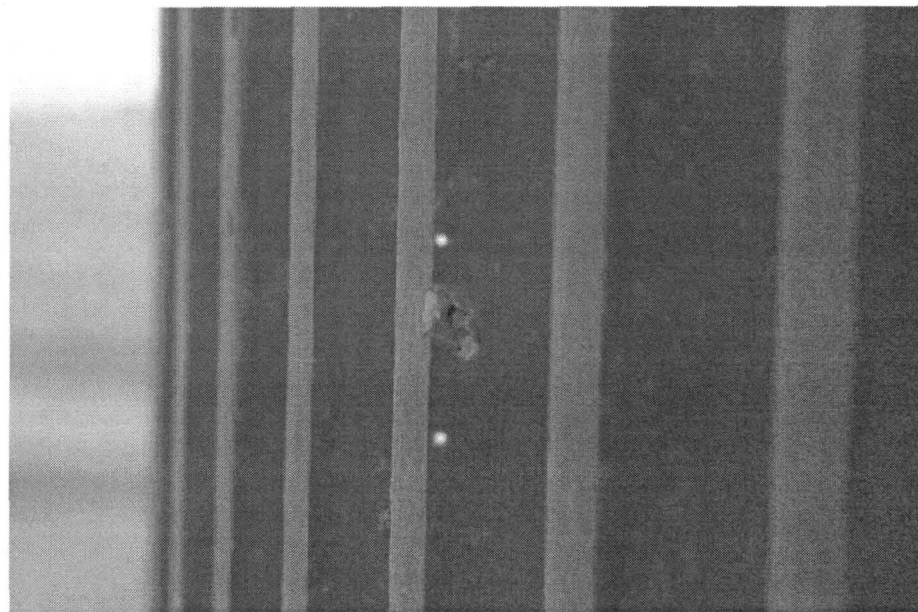
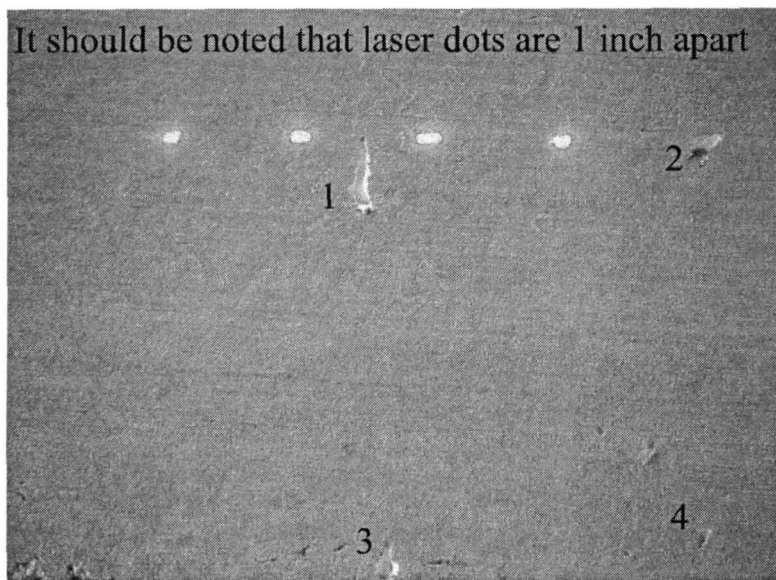
Interestingly, this measurement allowed observation of the ET contraction during fill and allowed swing arm adjustments.



Number 3: Remote Measurements of External Tank Damage



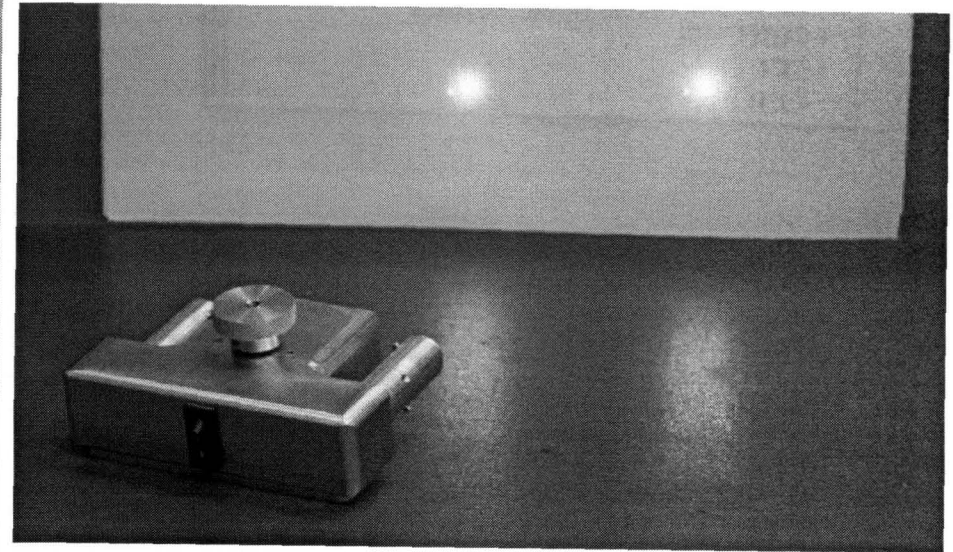
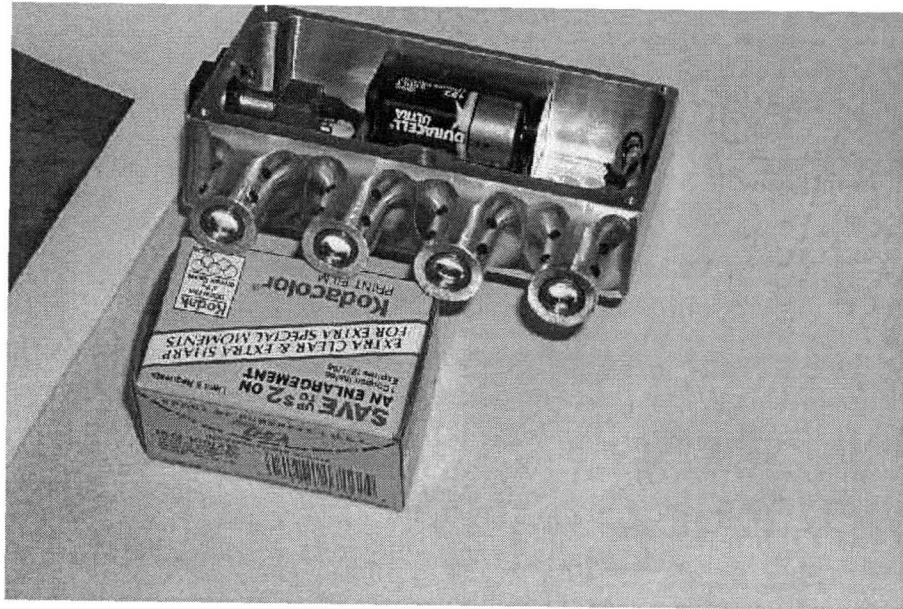
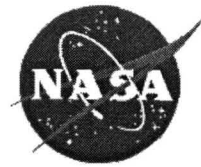
It should be noted that laser dots are 1 inch apart



The above images show bird scratches and hail damage on the External Tank. Such damage can be as far as 80 feet from a rail or walkway, but measurement of the size of such damage is necessary to determine if repair is needed. Shuttle asked for a way to remotely measure the size of such defects.



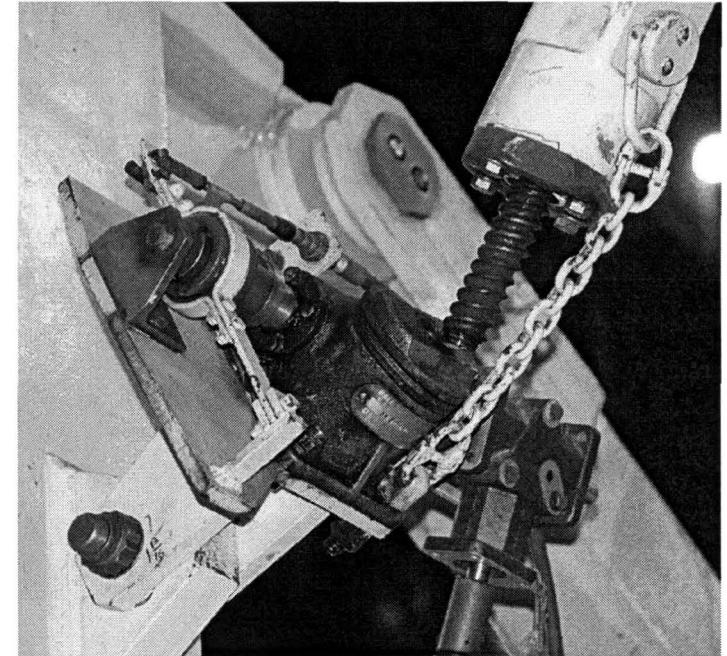
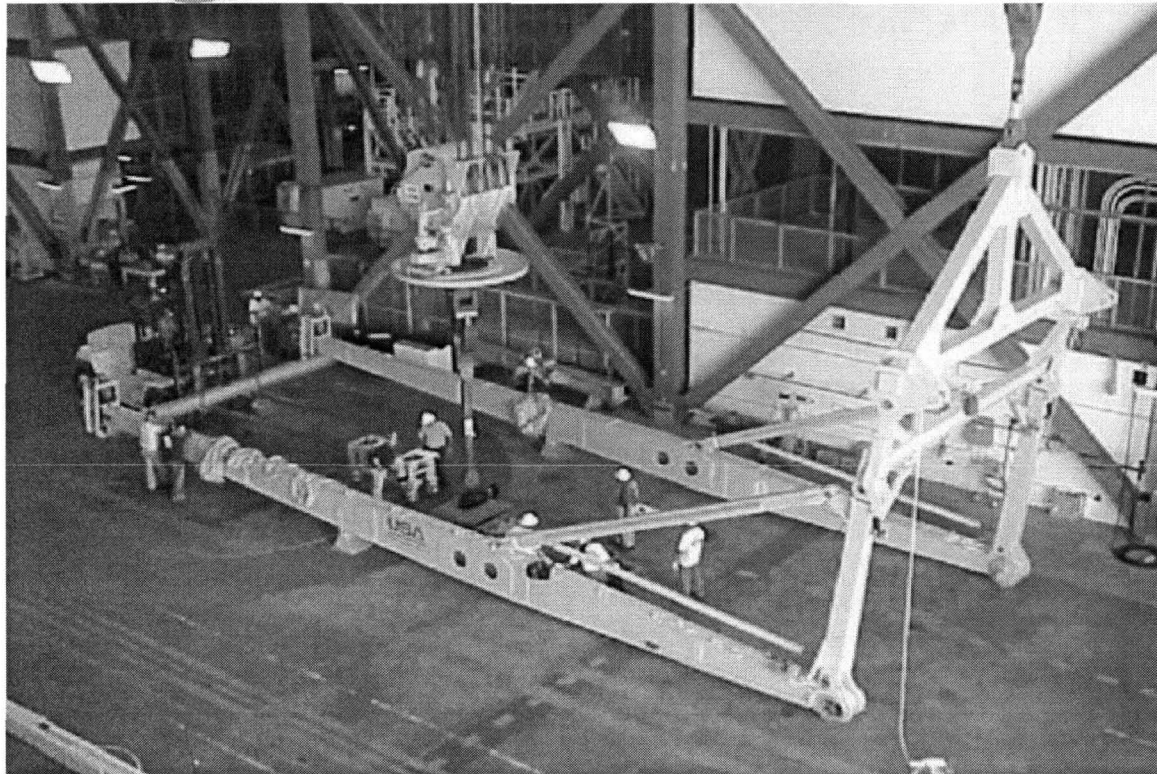
Number 3: Remote Measurements of External Tank Damage



We built a small device that launched four parallel red laser beams. Attaching this to a camera provides a scale in the image. A green version was built a few years later. This hardware was patented, commercialized, and is now sold by Armor Forensics primarily for crime scene documentation.



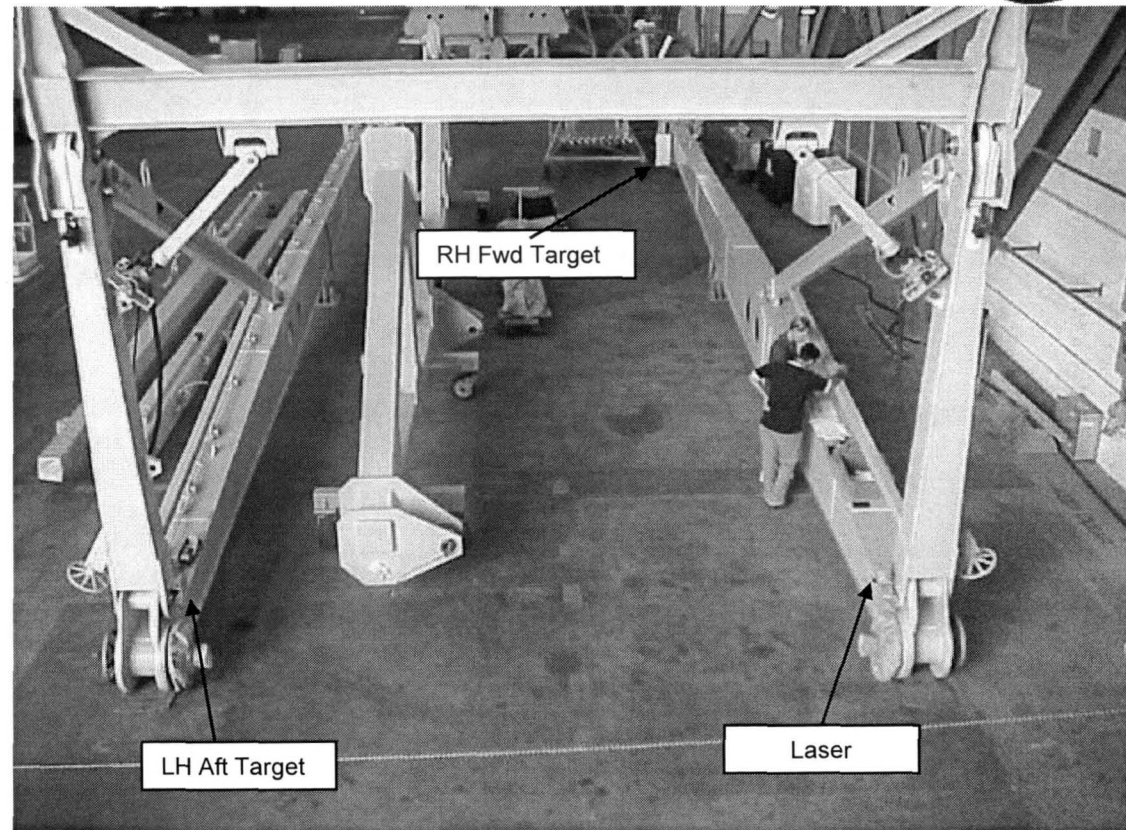
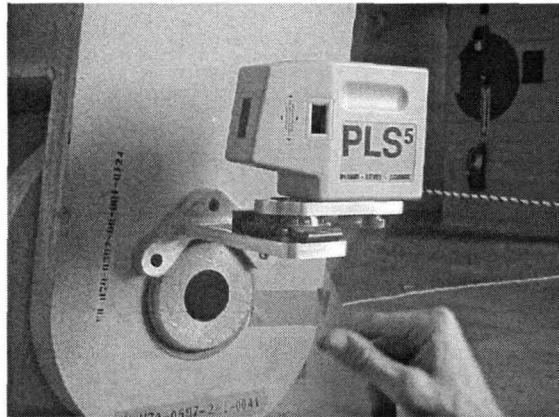
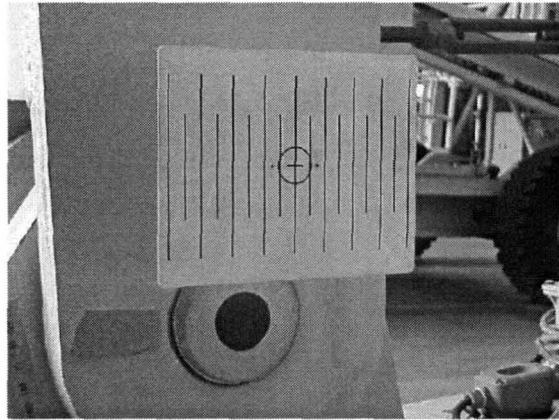
Number 4: Strain Measurement in the Orbiter Sling



The Orbiter Sling was damaged during a move operation and Shuttle personnel recognized that this was caused by induced strain. They contacted us and requested a strain sensor to prevent a reoccurrence.



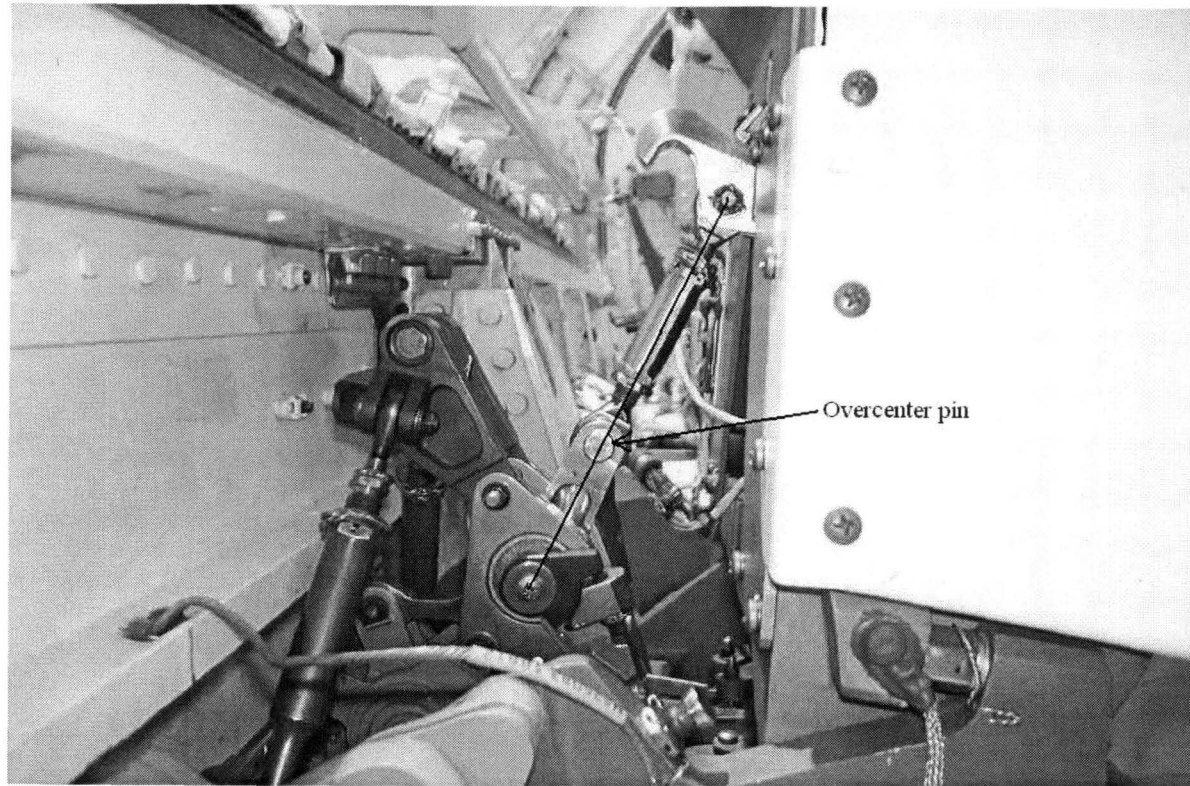
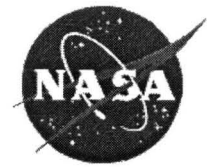
Number 4: Strain Measurement in the Orbiter Sling



The simplest solution was to install a 90 degree laser and two targets. Align the laser to the right forward target and monitor the left aft target during move operations. This provides a visual, real-time, strain measurement.



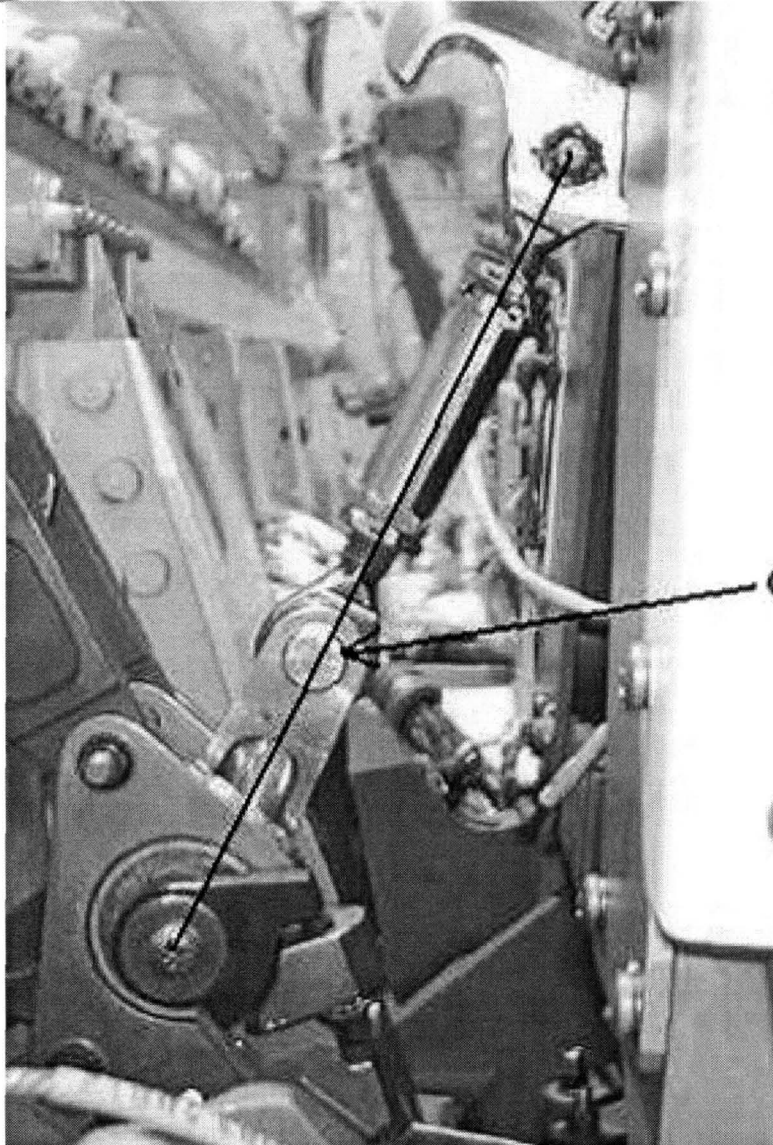
Number 5: Over-center Distance Measurement in an Over-center Mechanism



An over-center device is used to hold the payload bay robotic arm in place. This device must be configured such that the over-center pin is 0.026 ± 0.001 inches past the in-line position. This is a very difficult measurement to make, especially since no reference surface exists.



Number 5: Over-center Distance Measurement in an Over-center Mechanism

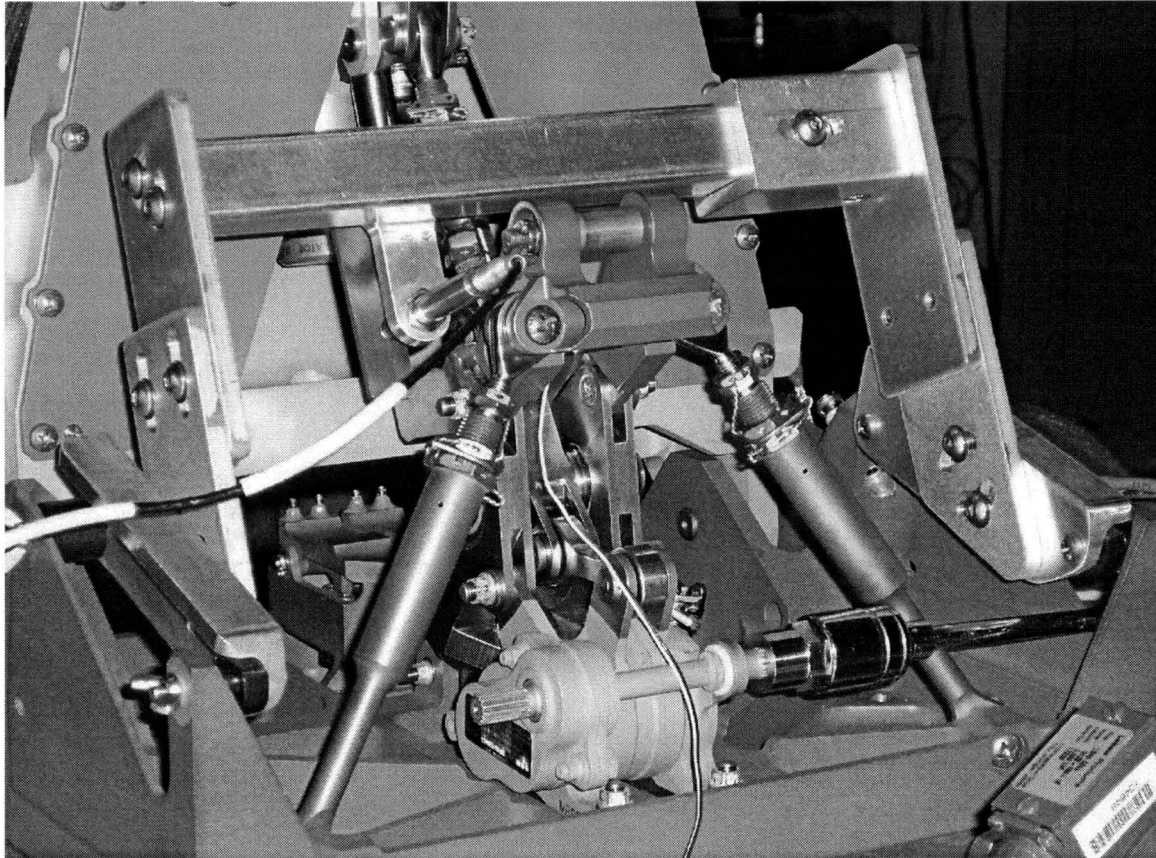


A frustrating situation. How do you locate the center of a pin relative to two other pins that can not be accessed?

The Shuttle team tried various approaches and settled on a strain sensor and a position sensor to estimate the in-line position, but this method was suspect and not accepted by much of the Shuttle engineering community.



Number 5: Over-center Distance Measurement in an Over-center Mechanism



We eventually solved this problem by modifying the Shuttle process and building new fixtures (as shown), but the lesson here is that the specification itself was poorly developed.



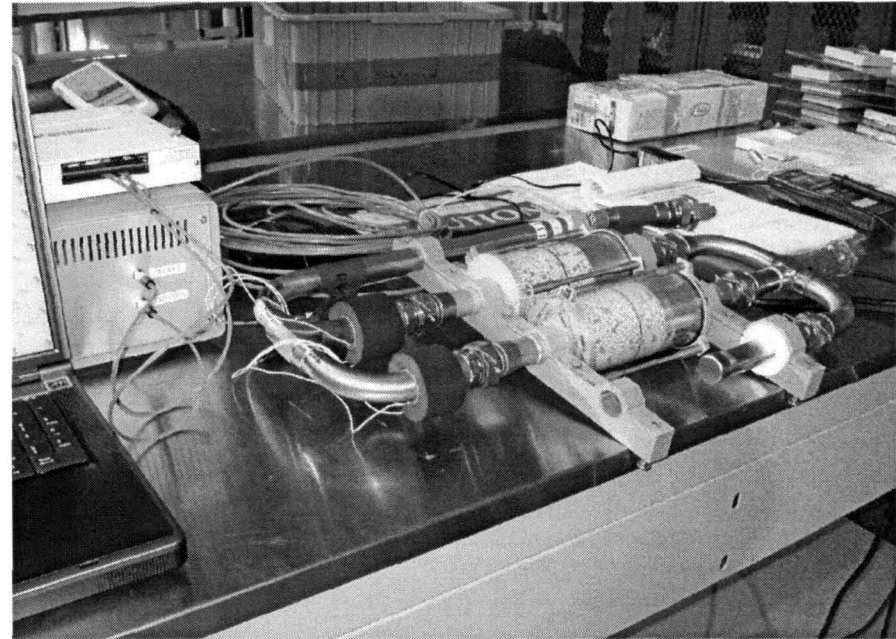
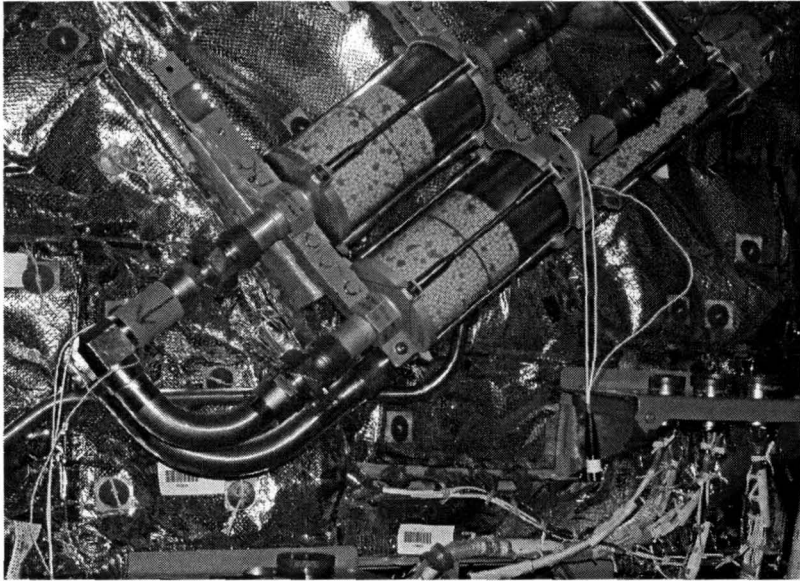
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Five examples were shown leading to the following lessons:

1. Be cautious when supplying too much resolution. It might become the new requirement.
2. Sometimes improving a measurement can lead to new insights into the hardware.
3. Some measurement devices find surprisingly new applications.
4. Providing visual cues for some measurements can help prevent processing damage.
5. Some measurements are necessary only because the specification was poorly developed.

Number 6: Monitoring Nitrogen Flow through the Window Cavity Conditioning System



Tom Moss has been developing a flow sensor that can monitor flow through the Orbiter desiccant canisters without opening the lines. This has been tested in the lab, on Orbiter hardware in the field, and in the Orbiter itself. Last May it became Crit I GSE and is currently in use in the field.